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ACHERNAR CAN BE A DIFFERENTIAL ROTATOR

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Abstract. We take advantage of interferometric measurements of Achernar to inquire on its internal rotational law. The reinterpretation of interferometric data and the use of fundamental parameters corrected for gravitational darkening effects and models of 2D-models of internal stellar structures, lead us to the conclusion that the star could not be a rigid, near critical, rotator but a differential rotator with the core rotating ~ 3 times faster than the surface.

1 Introduction

Achernar (α Eri, HD 10144) is the brightest Be star in the sky and as such it has deserved detailed observations. Of particular interest are the λ 2.2 μm interferometric observations carried out by Domiciano de Souza et al. (2003), which together with spectroscopic and spectrophotometric measurements enable us to inquire on what internal rotational law can account for its geometrical deformation.

2 Method and models

Achernar is an active Be star, even during a quiescent or apparent non-emission phase. The star had a small Hα emission at the epoch of interferometric measurements (Vinicius et al. 2005), which imnplies a flux excess at λ 2.2 μm of rougly 20% produced by a circumstellar disc. We may assume, however, that interferometry carried in the stellar polar directions are free from disc perturbations. The actual stellar equatorial radius can then be estimated requiring apparent area conservation: $R^2_{\rm sph} = R^{\rm app}_{\rm pole}(i) \times R_{\rm equat}$, where $R_{\rm sph}$ is the radius of the equivalent circular stellar disc derived by comparing measured fluxes with model atmospheres. The relation between the apparent i-dependent interferometric polar radius $R^{\rm app}_{\rm pole}(i)$ and the true stellar polar radius $R_{\rm pole}$ is given by:

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$$R^{\rm app}_{\rm pole}(i)/R_{\rm equat} = \{1-\left[1-(R_{\rm pole}/R_{\rm equat})^2\right]^2\sin^2 i\}^{1/2} \tag{2.1}$$

where i is the inclination angle. The use of the $V\sin i$ parameter corrected for gravitational darkening effects enables us to discuss the stellar rotational distortion as a function of the internal rotation law and of the amount of stored angular momentum. Inspired by model predictions of rotating stars by Meynet & Maeder (2000), we adopt the internal rotational law given by:

$$\Omega(r)/\Omega_{\rm core} = 1 - p.e^{-a.r^b} \tag{2.2}$$

where p determines the $\Omega_{\rm core}/\Omega_{\rm surf}$ ratio; b determines the steepness of the drop from $\Omega_{\rm core}$ to $\Omega_{\rm surf}$; a depends on the size or the core. 2D-models of stellar interiors were used to determine the changes of the polar and equatorial radii as a function of the energy ratio τ = kinetic energy/|gravitational potential energy| for a star with mass $M = 6.7 \pm 0.4 M_\odot$ near the end of the MS phase (Vinicius et al. 2005).

3 Results

The use of (2.1) and $R_{\rm equat}/R_\odot$ against τ enables us to compare the observed $(R_{\rm equat}/R_\odot, R_{\rm equat}/R_{\rm pole}, V\sin i)$ with the model predicted ones and determine:

$$\left.\begin{array}{ccc} p & = & 0.624 \pm 0.001 \\ \tau & = & 0.014 \pm 0.001 \\ \eta & = & 0.69 \pm 0.07 \\ V_{\rm e} & = & 308 \pm 16 {\rm km/s} \\ i & = & 52^o \pm 4^o \\ \Omega_{\rm core}/\Omega_{\rm surf} & = & 2.7 \end{array}\right\} \tag{3.1}$$

with $\eta = R_{\rm e}^3\Omega_{\rm e}^2/GM$ = ratio of centrifugal to gravity accelerations. The force ratio is $\eta < 1$ which indicates that the stellar equator is not at critical rotation. We note that for a plain rigid rotation approximation, Achernar would have $\Omega/\Omega_{\rm crit} = 0.8$, which corresponds to $\eta_{\rm rigid} = 0.66$.

It is interesting to note that the energy ratio $\tau = 0.014$ of our differential rotator is quite similar to the value of critical rigid rotators: $\tau_c = 0.015$. In the rigid rotation approximation the star would have $\tau_r = 0.011$, which implies that Achernar is possibly storing 30% more rotational energy that it would have if it were at rigid rotation.

References

Domiciano de Souza, A., Kervella, P., Jankov, S. et al. 2000, A&A, 407, L47

Meynet, G., Maeder. A. 2000, A&A, 361, 101

Vinicius, M.M.F., Zorec, J, Leister, N.V., Levenhagen, R.S. 2005, A&A, submitted